Requirements

RPG Special Topic

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This document corresponds to the web version of the VV&A RPG Special Topic of the same name and date. It has been modified to make it suitable for printing.

Introduction

This document discusses four topics related to requirements:

- Requirements Characterization -- how requirements are characterized in the VV&A RPG
- Terminology – definitions of the requirements terms used in the VV&A RPG
- Requirements Engineering -- how requirements should be generated and managed
- Requirements Analysis -- verification and validation of requirements

Other resources available for those preparing, evaluating, or improving simulation requirements include the *Requirements Engineering Journal*, the *Requirements Engineering Newsletter*, and links to software requirements engineering resources that the Software Engineering Institute (SEI) maintains.

Requirements Characterization

Simulations are built and/or modified to satisfy a set of requirements -- that collection of functionalities, representations, conditions, constraints, and assumptions that define the specific needs of a particular simulation use. For VV&A, this set of requirements is called the **M&S requirements** and is comprised of requirements from three domains - problem, user, and simulation.

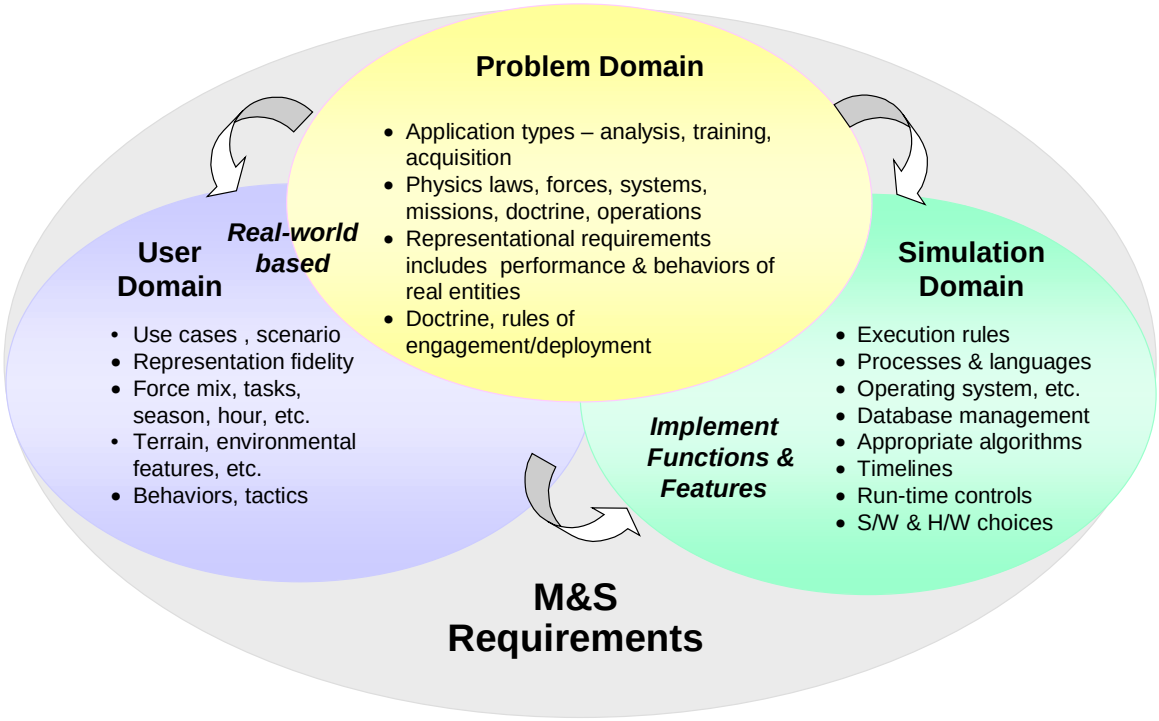
The **PROBLEM DOMAIN** is the universe that contains the subject or area of interest of the specified problem. Typically this encompasses a broad area because it includes the total area from which information can be obtained about the subject of the application (e.g., force structuring analysis; staff level training; analysis of alternatives for a system acquisition decision). Requirements associated with the problem domain are normally concerned with the nature of the problem (e.g., functionality (laws of physics); general missions; forces, systems, doctrine) and the over-all level of representation needed to produce the result.

The **USER DOMAIN** is the universe that describes the specific subject or field of use of the application. User domain requirements add the specifics to the Problem Domain Requirements to address real-world or realistic issues. User domain requirements are normally provided by subject matter experts (SMEs) who add detail about exactly how the entities, actions, tasks, and interactions occur within the constrains and assumptions of location, season, weather, and specific force structures.

The **SIMULATION DOMAIN** describes what the model or simulation needs in order to provide a credible solution for the problem. Requirements associated with the

simulation domain define capabilities and characteristics of the simulation itself (e.g., operating hardware and software; algorithms; level of fidelity; data and data formats). Simulation domain requirements address the issue of how the user domain and problem domain requirements are accommodated in the simulation implementation.

The relationships among these domains is shown in the M&S Requirements figure.



Terminology

Major M&S Requirement Categories

Individual requirements discussed throughout this document are normally categorized by type using these definitions:

M&S requirements. The collection of requirements that a model, simulation, or simulation federation must meet to serve a particular purpose. M&S requirements include problem domain requirements, user domain requirements, and simulation domain requirements.

problem domain requirements. The problem domain is that sphere of interest that delimits the reality that a model, simulation, or simulation federation is to represent at a suitable fidelity[1] to address a purpose, e.g., command and control, attrition, movement and maneuver. Problem domain requirements are descriptions of real world objects that a model, simulation, or simulation federation must represent and the doctrinal missions for each entity the User wants represented.

user domain requirements. The user domain is that sphere of interest that delimits the User's particular needs to which a model, simulation, or simulation federation will be applied. User domain requirements describe the intended methods of employing a model, simulation or simulation federation for a specific use.

simulation domain requirements. The simulation domain is that sphere of interest that is generated the methods-driven response to providing a solution to problem and user requirements. Simulation domain requirements describe the hardware and software environment needed to implement a model or simulation, including simulation architecture, software languages to be used, simulation management capabilities, visualization capabilities, user interfaces, interfaces to other simulation systems, command, control, communication, computer and intelligence (C4I) systems, operating requirements, etc.

The table below provides a sample list of requirements for several problems a simulation might be asked to address.

M&S Requirements for Specific Problems		
Problem Domain	**User Domain**	**Simulation Domain**
Problem: Train staff in developing Air Tasking Orders (ATOs)		
• General Theater setting • General Blue/Red OB • Theater C4I • Doctrine	• Specific Blue/Red OB • Specific Command Post • Season, Hour, Weather • C4I Interfaces • Tactics	• Computer Hardware • Software Coding Type • DBMS, Data Formats • Simulation Architecture • Simulation Interfaces
Problem: Determine the best course of action for a Contingency		
• General Theater setting • General Blue/Red OB • Theater C4I • Doctrine	• Specific Blue/Red OB • Specific Command Post • Season, Hour, Weather • C4I Interfaces • Tactics	• Computer Hardware • Software Coding Type • DBMS, Data Formats • Simulation Architecture • Simulation Interfaces
Problem: Train an F-15 aircrew in a simulated flight environment		

[1] see the special topic on Fidelity for additional information

M&S Requirements for Specific Problems		
Problem Domain	**User Domain**	**Simulation Domain**
• F-15 Flight Characteristics • F-15 Cockpit Layout • Switch Functionality • ROE	• Threat Representations • Season, Hour, Weather • C2 Interfaces • Location, terrain, etc • Tactics	• Computer Hardware • Software Coding Type • DBMS, Data Formats • Simulator Architecture • Simulator Interfaces

Additional M&S Requirements Groupings

Representational Requirements

VV&A practitioners have found it convenient to group representations of entities, actions, tasks, and interactions together as **representational requirements**. Representational requirements are that subset of the M&S requirements that specifically describes the required states or behaviors of the things the model or simulation represents including the modeled entities, their properties and their dependencies. This term provides a means of describing all facets of the need to represent an entity and/or functionality without regard to the domain origin of the requirement, i.e., problem, user, or simulation domain. This grouping crosses domains as shown in the example below.

Example Representational Requirements Origin	
Requirement	**Origin**
• System representation	Problem domain
• Force representations	Problem domain
• Rules of engagement	Problem domain
• Scenario	User domain
• Weather representation	User domain
• Terrain representation	User domain
• Visual representation	User and simulation domain
• Elapsed time	User and simulation domain

Refined Requirements

For each new model, simulation, or simulation federation, a set of requirements is developed that governs how it is to be built (i.e., what the model, simulation, or simulation federation needs to be able to do). These requirements are continuously refined as more information is obtained and trade-offs are made during development and any subsequent reuse. This continual refinement ensures the M&S Requirements

are fully understood and fully detailed during the development of the conceptual model[2] and simulation design specifications.

For reuse of a legacy simulation, the User assesses the viability of the simulation through a requirements analysis of the as-built requirements and conceptual model. The User then revises those requirements as needed to address the current problem. These newly refined requirements detail which capabilities of the existing simulation will be retained as-is; which capabilities need to be modified, and what capabilities that need to be added to the simulation to make it fit the current application. Additional requirements are defined as needed and all requirements are again continuously refined to ensure they are fully integrated into the conceptual model and simulation design specification.

Importance of Requirements

It is difficult to overstate the importance of a good set of requirements. The example below, although specifically addressing software, is applicable to simulation.

> Example:
>
> Many software project failures have been attributed to requirements engineering issues. These include poorly documented requirements, requirements that were impossible to satisfy, requirements that failed to meet the needs of users, and requirements creep—the gradual inclusion of unanticipated, undocumented, and poorly considered requirements.
>
> Even when projects do not fail outright, software developers now recognize that errors occurring early in the development life cycle, particularly at the requirements definition stage, turn out to be the most difficult and costly to fix. This is especially true when the errors are not discovered until late in the life cycle—perhaps at implementation. [SEI Interactive, 1999]

Requirements Engineering

Participants

Developer

The Developer (for legacy simulations, this is the person or group responsible for preparing the code for use) derives requirements that can be traced back to one or more of the original requirements, which are needed to support development of the conceptual model and simulation specifications. As necessary, the Developer should propose reorganizing, rephrasing, and recasting User-provided requirements to

[2] see the special topic on Conceptual Model Development and Validation for additional information

minimize ambiguities and inconsistencies. Formal languages and grammars may be helpful as a means of ensuring that requirements are consistent and logically coherent.

V&V Agent

The V&V Agent can help refine the M&S requirements by identifying inconsistencies and gaps in the set and by identifying implicit requirements during requirements verification. The V&V Agent may also uncover implicit or missing requirements in the process of performing other verification and validation tasks (e.g., conceptual model validation;[3] design verification). The conceptual model validation process, in particular, is likely to identify both inconsistencies and implicit requirements.

Implicit requirements should be made explicit to ensure that the requirement doesn't "disappear" in the future, possibly invalidating the simulation. Inconsistent requirements should also be made consistent. However, although the V&V Agent can assist in this process by making recommendations, it is the responsibility of the User, assisted by the Developer, to resolve requirement consistency problems.

The V&V Agent may also discover problems in measuring and testing requirements and propose requirement changes to better support measurement and testing of simulation capabilities. Not all requirements can be completely tested. The V&V Agent and User should discuss issues related to the viability and affordability of demonstrating satisfaction of particular requirements.

The fact that a requirement is untestable or inconsistent does not invalidate the statement of the requirement, but it does have significant impact on how the requirement should be addressed. Untestable requirements may be partially satisfied through face validation. The V&V Agent should state to what degree the requirement can be validated or tested and how much risk[4] is involved. There is little difference between a situation in which validation cannot be performed and one in which the validation investigation shows the representational capability of the simulation falls short of the simulation requirement. In both cases, failure to demonstrate that a requirement is satisfied increases the risk in using the simulation for its intended purpose. Whether that increased risk is acceptable is for the User to decide.

User

The User, as the final authority in setting all requirements, should assist the Developer and the V&V Agent as needed to clarify, comment upon, understand, and revise any derived requirements.

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[3] see the special topic on Conceptual Model Development and Validation for additional information
[4] see the special topic on Risk and Its Impact on VV&A for additional information

Requirements Generation

> Example:
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> Software engineers initially focused on programming methods, then on design methods, and are now focusing on requirements methods, in an attempt to introduce more discipline in the software engineering process. In the early days, requirements were developed in English text, but over time have evolved into structured and in some cases formal specifications. More recently there has been interest in requirements elicitation, because working with non-technical people can be among the most challenging areas of software development. [SEI Interactive, 1999].

Characteristics of Good Requirements

Good Requirement Characteristics
• Cear and unambiguous, with unique designation for each specific requirement
• Expressed in a way that can be understood by the User, the domain SMEs, and the Developer to mean the same thing
• Even obvious requirements are stated (User and Developer may differ about what is “obvious”)
• Consistent with other requirements for the simulation
• Testable (or, at least, satisfaction of a requirement can be demonstrated in some objective and measurable way)
• Organized to facilitate requirements modification during the course of the project: – structured topically – ranked as essential (requirement) or as expected or desirable (characteristic, not a rigid requirement) according to what the simulation needs to be able to do – amenable to elaboration as requirements are translated into high-level and then detailed specifications
• Viable or achievable (a good requirement is not impossible to satisfy; it can be implemented)
• Can accommodate tracing both forward to simulation design and implementation and backward from simulation implementation to the original objectives

The User establishes the requirements. The User determines what the simulation should be capable of doing. However, the User should consult subject matter experts (SMEs)[5] with requirements engineering experience in order to articulate the simulation domain requirements so the requirements will have the attributes listed in the table above.

[5] see the special topic on Subject Matter Experts and VV&A for additional information

Requirements Management

The following table presents some good practices for managing requirements, an assessment of the costs to introduce the practice and apply it, and key benefits from those practices [Sawyer, et.al., 1999].

Requirements Management Good Practices			
Task	**Cost to Introduce**	**Cost to Apply**	**Key Benefit**
• Uniquely identify each requirement	Very low	Very low	Provides unambiguous references to specific requirements
• Define policies for requirements management	Moderate	Low	Provides guidance for all involved in requirements management
• Define traceability policies	Moderate	Moderate to high	Maintains consistent, traceability information
• Maintain a traceability manual	Low	Moderate to high	Records all project-specific traceability information
• Use a database to manage requirements	Moderate to high	Moderate	Makes it easier to manage large numbers of requirements; for small endeavors, use of a database approach is no more costly than manual methods
• Define change management policies	Moderate to high	Low to moderate	Provides a framework for systematically assessing change
• Identify overall system requirements	Low	Low	Finds requirements likely to be most expensive to change
• Identify volatile requirements	Low	Low	Simplifies requirements change management
• Record rejected requirements	Low	Low	Saves repeating analysis when rejected requirements are proposed again

Requirements Configuration Management

Additions, refinements and other changes to the set of M&S requirements are inevitable during the development and life cycle of a simulation. The originating requirements provided by the initial User will grow during the project as requirements are refined, additional requirements are derived, implied requirements are made explicit, and newly discovered requirements are included. The configuration management process must allow efficient but controlled changes. The requirements database should track when and by what authority changes and additions are made to every requirement. The individual or group authorized to change or add requirements must balance responsiveness to genuine project needs with the importance of requirements stability during development and the problems of “requirements creep.”

Change authorization should be a formal process aided by automation to keep the process responsive (e.g., a configuration control board or review panel whose members are able to assess the programmatic and technical impacts on development and V&V). All change requests should be documented and provided to the V&V Agent. The V&V Agent should have an opportunity to assess the impact of the change on simulation validity as well as on the total set of requirements. The V&V Agent should ensure that those authorized to change simulation requirements are properly apprised of such impacts. Regression testing can also be used to ensure that original capabilities remain intact.

The configuration management process established for the simulation can be useful in the V&V process. If a distributed simulation application involves several simulations, several different configuration management programs may be involved. Characteristics of a good configuration management system from the V&V viewpoint include

- strict control of requirements
- stability of requirements (considered, deliberate changes)
- effective version identification
- a solid trace of requirements (down to each supported version and to the simulation system components associated with each requirement).

Requirements Analysis

Frequently the initial set of requirements is incomplete, inconsistent, and contains errors. An important early verification and validation (V&V) responsibility is requirements verification, also called requirements analysis. Early requirements verification helps the User ensure that the requirements will lead to a simulation that can address the needs of the application efficiently and effectively. Early requirements verification can also identify and thus prevent potentially inappropriate commitments (such as ill-advised specifications or problematic development contracts). There are three major aspects of requirements verification:

- to ensure that the requirements are internally consistent, clear and unambiguous, and logically comprehensive
- to support (facilitate) tracing requirements to (and from) the simulation conceptual model, simulation specifications, simulation design, and simulation implementation
- to ensure that the requirements correctly reflect the User’s intent

Additional V&V tasks associated with requirements verification are discussed in the V&V Agent core documents (e.g., V&V Agent Role in the VV&A for New Simulations)[6].

If the requirements contain extraneous elements (i.e., elements that do not contribute to satisfying the user's intent), they will make the simulation development unnecessarily expensive. If the requirements have excessive demands for accuracy or fidelity[7] beyond those required by the specified use, they can also make the simulation development and preparation unnecessarily expensive. If the requirements are not stringent enough to ensure that simulation capabilities will satisfy the needs of the application, the simulation can end up being unsatisfactory.

Requirements Analysis Techniques

Two of the standard techniques employed in requirements verification are requirements review and requirements tracing.

- **Requirements Review.** Requirements review is usually more effective when different classes of requirements (e.g., simulation, problem, and user domain) are treated separately.
- **Requirements Tracing.** Requirements tracing is a straightforward task of incalculable value. To support V&V activities, requirements should be traced through all simulation development phases. A requirements database could also reference V&V tools and techniques that are used relative to the requirements, to any test cases and test scripts applied, and to results of V&V efforts. Likewise, tracing from validation results back to requirements is essential to support risk management for effective accreditation decisions.

Additional information about these and other techniques is available in the reference document on V&V techniques.[8]

Requirements Analysis Team

Requirements verification or analysis is normally done by a group of people that includes, as a minimum, the User, M&S PM, Developer, SMEs, Accreditation Agent, and V&V Agent. This team has only an advisory role. The User, as the one who has the authority to determine requirements, may or may not heed recommendations and suggestions resulting from the effort.

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[6] see the core document on V&V Agent Role in the VV&A for New Simulations and other core documents for additional information
[7] see the special topic on Fidelity for additional information
[8] see the reference document on V&V Techniques for additional information

Administrative Structure

A common problem with simulation development is a lack of administrative structure that can allow (or support) early requirements verification, with the consequence that a formal requirements verification effort often begins after inappropriate development decisions and resource commitments have been made. Mechanisms to enable early analysis are important, but it is better to do requirements verification late than not at all.

References

DoD Modeling and Simulation Office (DMSO), "Federation Development and Execution Process (FEDEP) Model," Version 1.5 (draft), 8 December 1999.

SEI Interactive: Software Requirements Engineering, Volume 2, Issue 1, "Introduction," March 1999.

Sawyer, Pete, Ian Sommerville, and Stephen Viller, "Capturing the Benefits of Requirements Engineering," *IEEE Software*, March/April 1999, pp. 78-85).

External Links in This Document

Links web site:
http://interactive.sei.cmu.edu/Features/1999/March/Links/Links.mar99.htm

SEI web site: http://www.sei.cmu

RPG References in This Document

select menu*: RPG Core Document*, select item: "V&V Agent Role in the VV&A of New Simulations"

select menu*: RPG Special Topics*, select item: "Conceptual Model Development and Validation"

select menu*: RPG Special Topics*, select item: "Fidelity"

select menu*: RPG Special Topics*, select item: "Risk and Its Impact on VV&A"

select menu*: RPG Special Topics*, select item: "Subject Matter Experts and VV&A"

select menu*: RPG Reference Documents*, select item: "V&V Techniques"

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